

**FOURMILE CANYON CREEK AND  
WONDERLAND CREEK  
MAJOR DRAINAGEWAY PLANNING  
PHASE A REPORT  
ALTERNATIVES ANALYSIS**

**EXECUTIVE SUMMARY**

The development, evaluation, and recommendation of floodplain alternatives to mitigate existing flooding in both the Fourmile Canyon Creek and Wonderland Creek floodplains within the City of Boulder (City) and Boulder County are presented in this report. This effort is jointly sponsored by the Urban Drainage and Flood Control District (UDFCD) and the City of Boulder, Colorado.

**Purpose and Objectives**

The purpose of the study is to analyze the existing and future drainage conditions within both the Fourmile Canyon and Wonderland Creek floodplains, develop alternate drainageway planning concepts to mitigate existing flood damages taking into consideration the impacts of the spill flows from Fourmile Canyon Creek to Wonderland Creek, and prepare a preliminary design of an alternative selected by the Project Sponsors. The study is divided into two phases. The first phase (Phase A) of which this report is a part covers the hydrologic, hydraulic, and alternate evaluation aspects of the project. The second phase (Phase B) will cover the preliminary design of the selected alternate(s).

**Planning Process**

The initial planning effort began in June of 1999 and both a Phase A and Phase B study were completed for Fourmile Canyon Creek. Following the review and input from the Independent Review Panel (IRP) comprised of floodplain experts in 2000, it was recommended that in order to develop a more complete solution for flooding on Fourmile Canyon Creek, a combined Phase A Alternate Analysis report should be undertaken as a combined study of both Fourmile Canyon and Wonderland Creeks. This combined Alternate Analysis began in the Fall of 2006. Since that time, a series of progress meetings have taken place to exchange information and discuss ideas and findings of the combined study. The progress meetings were regularly attended by representatives of the sponsoring agencies. Concurrent with the progress meetings, a series of public meetings were conducted to discuss the planning effort and solicit public input.

The Project Sponsors will review the Phase A report and make a decision on the alternative that is to be studied in greater detail in Phase B of this planning effort. In Phase B, the consultant will prepare a preliminary design of the alternative(s) selected by the Project Sponsors for both streams. The type, size, location of various improvements will be developed in greater detail. In the process, cost estimates will be refined and the relative priorities and phasing of these facilities will be identified. A final Phase B report will be published following selection of the preferred alternative. The Phase B report will serve as a planning tool for the Project Sponsors and private development within the Fourmile Canyon Creek and Wonderland Creek floodplains.

**Background Information**

The study area includes the Fourmile Canyon Creek floodplain from the mouth of the canyon to its confluence with Boulder Creek and the Wonderland Creek floodplain from downstream of Wonderland Lake to its confluence with Goose Creek. The Fourmile Canyon Creek spill floodplain, which is located between the Fourmile Canyon Creek and Wonderland Creek floodplains from upstream of Broadway to approximately 19<sup>th</sup> Street, is included in the study area.

Major drainageway planning documents were previously developed for Fourmile Canyon Creek and Wonderland Creek by Greenhorne & O'Mara, Inc in 1984 and 1987 and for Wonderland Creek by Boyle Engineering in 2002. Due to recent development that has occurred in the floodplain and inaccuracies in the original studies, the City of Boulder commissioned a re-study of the Fourmile Canyon Creek floodplain in 1997 and the Wonderland Creek floodplain in 2005. Love & Associates was retained by the City to prepare a Letter of Map Revision (LOMR) submittal to FEMA for these two streams and the LOMR was approved by various City Boards and the City Council in early 2006. The LOMR was submitted to FEMA in March, 2006 and approved by FEMA in November, 2006. The new floodplains became regulatory following the appeal period in late March, 2007.

The LOMR submittal for these two creeks indicated significant problems with the original FEMA regulatory studies, resulting in additional properties being located within the two floodplains. Of particular importance, the re-study identified reaches of Fourmile Canyon Creek west of 19<sup>th</sup> Street, where, once the channel capacity is exceeded, flood flows overtop the south bank of the creek and flow in a southeasterly direction towards Wonderland Creek. These “spill flows” result in a reduction of flows in Fourmile Canyon Creek downstream of 19<sup>th</sup> Street but also result in an increase in the flows in Wonderland Creek. During the 100-year flood event, approximately 3,300 cubic feet per second (cfs) is in Fourmile Canyon Creek near the mouth of the Canyon, of this amount approximately 1,600 cfs will overtop the south bank spill and flow toward Wonderland Creek. The remaining 1,700 cfs will remain in the Fourmile Canyon Creek Channel. Likewise, the 100-year discharge in Wonderland Creek significantly increases downstream of the spill inflow. Some of the spill flows return to Fourmile Canyon Creek near 19<sup>th</sup> Street but the majority of the spill remains in the Wonderland Creek floodplain.

**Damage Analysis**

All property, structures and infrastructure within the 500-year floodplain were included in the damage analysis which was undertaken as a part of this master planning effort. The damage analysis was calculated using the UDFCD Methodology for Evaluation of Feasibility: Multi-Jurisdictional Urban Drainage and Flood Control Projects. Flood damages were calculated for the 2-, 5-, 10-, 50-, 100-, and 500-year flood events. For the economic analysis, a 50-year project life was chosen, which corresponds to a typical structure life. A 6% annual interest rate was selected, which corresponds to the cost of borrowed capital for the entities involved and a 3% annual rate of inflation was assumed. The net discount rate used in present value calculations was 3%.

**Identification of Potential Flood Mitigation Alternates**

Early in the study, a broad range of alternates were identified. These alternates were screened following an analysis of each stream and detailed discussions held during progress meetings on a reach by reach basis for each stream. A wide array of options were looked at as potentials for mitigation of the flooding ranging from a ‘do-nothing’ status quo alternate to construction of a 100-year flood channel for each stream confining the spill from Fourmile in its own channel.

**Alternates Analysis**

A number of alternates were reviewed as a part of this study. The damage analysis and alternate costs for the previous Fourmile Canyon Creek (2000) and Lower Fourmile Canyon Creek (2002) reports were updated and benefits and costs for two additional alternates were developed. The two additional alternates considered for both streams included a High Hazard Containment and Floodproofing of Structures in the spill area between Fourmile Canyon and Wonderland Creeks alternate. Original alternates considered in the initial *Fourmile Canyon Creek Major Drainageway Master Plan* also included both a 50- year and 100-year channel alternate.

The 100-year channel would be designed by an inter-disciplinary team of engineers, geomorphologists and biologists to emulate a natural channel. This alternate would eliminate spills from Fourmile Canyon Creek to Wonderland Creek during the 100-year or smaller flood event. The channel would be designed to UDFCD and City criteria with FEMA and City required freeboard. The 50-year alternate for Fourmile Canyon (only) would contain the 100-year flows but would have no freeboard built into the design. The Urban Drainage and Flood Control District, based on legal opinion from its counsel, has indicated reluctance to participate in any Alternate which includes containment or reduction of the spill unless downstream property owners’ concerns are properly addressed as this would negatively affect downstream properties on Fourmile Canyon Creek.

The High Hazard Zone is defined as those areas where the product number of velocity (measured in feet per second) times flow depth (measured in feet) equals or exceeds four, or where flow depths equal or exceed four feet. These portions of the 100-year floodplain pose an unacceptably high hazard to human safety. In the high hazard zone, the construction, expansion or enlargement of any structure intended for human occupancy or establishment of a new parking lot is prohibited. The High Hazard Containment alternate would remove structures identified in either stream from the City’s High Hazard Flood Zone through direct purchase of the property, the enlargement of road crossing structures, channel excavation, and/or floodproofing or a combination thereof. This alternate does not eliminate the out of channel bank floodplain; however, it reduces flood levels to those structures in the High Hazard Zone for increased safety when evacuating occupied buildings and allows for emergency access to residential structures.

Floodproofing is a combination of adjustments and/or additions of physical features installed in, on or around individual structures designed to eliminate or reduce the potential for flood damage to the structure. Floodproofing consists of the techniques and approaches for preventing or minimizing flood damages to a structure and its contents in flood hazard areas. Floodproofing techniques range from: the construction of levees and flood walls around a structure, to installing water-tight doors and windows, physically raising the structures elevation using fill or pilings, measures designed to reduce water seepage

and/or resist lateral pressure from flood water in the structure, etc. Floodproofing measures may be applied to new structures as well as retrofitting existing structures which may allow for development within the floodplain in low hazard areas. The purpose of floodproofing is to minimize flood damages by either keeping floodwaters away from damageable property or making the property less susceptible to damages when floodwaters reach the structure. Floodproofing does not eliminate all flood damages but can, if done correctly, significantly reduce damages from flooding. The City may offer guidance and disseminate information regarding various floodproofing techniques; however, it would be the responsibility of the individual property owner to implement this alternate for their own individual properties.

Alternates proposed are compared to the Status Quo or Maintain Existing Conditions alternate. Maintain existing floodplain configuration would adopt the new floodplain mapping without proposing mitigation improvements at this time. Additional non-structural methods including flash flood forecasting and warning systems and evacuation plans would also be recommended for implementation. Flood insurance and floodproofing of structures would also be recommended (at the individual property owner’s expense). Floodplain regulations would be strictly enforced. Post flood relief would be provided. This alternate requires no new funding, but may sacrifice opportunities to greatly improve Fourmile Canyon Creek and mitigate flooding in the future. A “Do Nothing” solution would offer no opportunity to mitigate spills and flooding to the south of Fourmile Canyon Creek and would offer no opportunity to eliminate flooding to the Waldorf or Crestview Elementary Schools.

Reach by Reach cost estimates were prepared for the each of the alternates analyzed (five in the Fourmile Canyon Creek floodplain and four in the Wonderland Creek floodplain).

Each of the alternates analyzed for both streams will still incur an expected damage during flood events. Examples of these damages would include isolated bank erosion locations in the constructed “natural” channel alternate or wide spread damage in the maintaining of the existing floodplain configuration alternate.

One method commonly used to compare alternatives is the benefit/cost (B/C) ratio. In general, the higher the B/C ratio the more cost effective is an alternate. In this study, the benefit/cost ratio compares the total cost to implement a flood control alternative with the benefits that would be realized if that flood control alternative were implemented. The total cost to implement a flood control alternative was calculated as the sum of the construction costs, property acquisition costs (land and structure), right-of-way required to implement the alternate and O&M costs. The benefit that would be realized if the flood control alternative is implemented was calculated as the difference between flood damages under existing conditions minus flood damages that would be incurred after implementation of the alternative.

Benefit/Cost Ratio = 
$$\frac{[\text{Existing Flood Damages}] - [\text{Future Flood Damages with Alternative in Place}]}{\text{Cost to Implement Alternative}}$$

A B/C ratio greater than one (1) indicates the benefit received is greater than the cost to implement the alternative. A B/C ratio equal to one (1) indicates the benefit received is the same as the cost to implement the alternative. A B/C ratio less than one (1) indicates the benefit received is less than the cost to implement the alternative.

Comparison of benefits and costs must be made for the same time frame. Benefits stemming from reduced flood damages occurring annually over the life of the project cannot be compared directly with construction costs, which generally occur over a short period of time near the beginning of the project. All benefits and costs must be converted to either present value or annual amounts before comparison, using an appropriate discount rate, which accounts for the time value of money. For this study all costs were converted to present value. Present value calculations assumed a 50-year project life, which corresponds to the typical structural life, and a discount rate of 3% (6% annual interest rate minus 3% annual rate of inflation).

The benefit/cost ratio for each alternate for the entire study reach of each creek is as follows:

| <u>Fourmile Canyon Creek</u> |                               |      |
|------------------------------|-------------------------------|------|
| Alternate 1                  | 50-Year Channel B/C =         | 1.43 |
| Alternate 2                  | 100-Year Channel B/C =        | 1.34 |
| Alternate 3                  | Status Quo B/C =              | 0.00 |
| Alternate 4                  | Floodproofing B/C =           | 1.96 |
| Alternate 5                  | High Hazard Containment B/C = | 0.08 |

| <u>Wonderland Creek</u> |                               |      |
|-------------------------|-------------------------------|------|
| Alternate 1             | 100-Year Channel B/C =        | 1.92 |
| Alternate 2             | Status Quo B/C =              | 0.00 |
| Alternate 3             | High Hazard Containment B/C = | 0.44 |
| Alternate 4             | Floodproofing B/C =           | 3.64 |

There are numerous intangible benefits that would arise from the implementation of flood mitigation improvements. By definition, intangible benefits are difficult to measure and are not directly quantifiable in terms of dollar value or dollars spent for their usage. The intangible benefits that may be realized through flood mitigation include the following:

- Improved traffic movement during floods.
- Improved emergency response.
- Improved public health and safety.
- Improved environment, water quality and riparian habitat.
- Lower flood insurance.
- Potential for scientific, educational, historical amenities.
- Increased property values.
- Creation of cultural, educational, and scientific resources.

Because intangible benefits are not directly quantifiable in terms of a dollar value they are not included in the benefit/cost analysis. As a result, the benefit/cost ratios are lower than what would be realized if dollar values were placed upon the intangible benefits.

In addition to the benefit/cost ratios presented above, a number of additional evaluation factors should be considered when choosing a course of action to mitigate flood damages within the Fourmile Canyon Creek and Wonderland Creek floodplains. Below is a list of some of the potential evaluation factors:

Evaluation Factors

- Flood Mitigation
  - Life Safety
  - Property damage
- Environment
  - Temporary Disturbance
  - Long-term benefit
  - Groundwater
- Transportation
  - Automotive
  - Bicycle/Pedestrian
- Development/Re-Development
  - Growth Management
  - Affordable Housing
- Aesthetics
- Benefit/Cost Ratio
- Construction Cost
- Recreation
- Permitting Requirements
- Impacts to Fourmile Canyon Creek
- Impacts to Wonderland Creek
- Conformance with other Planning Documents
- Competing Priorities
- Public Acceptance
- Operation and Maintenance

Bigger floods can and will occur. This statement holds true whether you are talking about a 10-year, 100-year or 500-year flood event. The Fourmile Canyon Creek and Wonderland Creek floodplains have not had a significant flood in the recent documented past. The public awareness of the significance of the flood situation is low since many of the residents in the floodplain have not seen the results of a disaster, or had to clean up after a flood in their neighborhood or experienced the injury to or loss of a family member or friend in a flood event.

Recommended Alternate

The contract Love & Associates, Inc. has with the Urban Drainage and Flood Control District requires that the consultant make a recommendation as to the best overall alternate solution, taking into account a variety of information developed throughout the master planning process for both Fourmile Canyon and Wonderland Creeks.

The firm of Love & Associates, Inc. is recommending a combination alternate for both Fourmile Canyon Creek and Wonderland Creek. In developing the Recommended Alternate we evaluated in combination the alternates utilizing a reach-by reach approach.

For each creek the recommended alternate consists of a combination of the 100-Year Channel, High Hazard Containment, Floodproofing and Maintain Status Quo.

In Reaches 5 and 6 of Fourmile Canyon Creek, the 100-Year Channel and 50-Year Channel alternates result in a change in the spatially varied flow distribution in the floodplain which would require channelization to the confluence with Boulder Creek. Love & Associates, Inc. believes that complete channelization of Fourmile Canyon Creek from Reach 5 or 6 to its confluence with Boulder Creek is not a viable option. The Urban Drainage and Flood Control District has indicated they are not willing to participate in a solution which incorporates containment/channelization of all flows from upstream to the confluence with Boulder Creek. Since these alternates change the flow distribution that currently exists in the floodplains of both streams, channelization creates both liability and life safety risks if bigger floods were to occur. Lands could be inundated by the introduction of flood waters where they would not have existed prior to the re-distribution of flood waters by either of these alternates. Love & Associates, Inc. is not recommending either a 50 or 100-year channel alternate upstream of the spill zone for these reasons. In some downstream reaches where the 100-year alternate resulted in a B/C ratio greater than 1, the 100-year alternate is recommended with a reduced conveyance required. In Reaches 2b and 4 on Fourmile Canyon Creek the 100-year channel altternate is recommended. The 100-year channel downstream of the spill zone contains the reduced flow that remains after the spill from Fourmile Canyon Creek to Wonderland Creek. Likewise, in Reaches 4 and 5 on Wonderland Creek where the 100-year alternate resulted in a B/C ratio greater than 1, Love & Associates is recommending this alternate. For both creeks the 100-year channel is designed to contain the 100-year discharge and provide a minimum of 1’ of freeboard. This freeboard contains the 500-year flow, making floodproofing unnecessary in these reaches. Additionally, in reaches where 100-year improvements are implemented, flood insurance would also no longer be required. It should be noted that unless 100-year improvements are implemented thus eliminating properties from the floodplain, flood insurance is required with all other solutions including a 50-year channel alternate and floodproofing which provides a degree of flood protection but does not remove the property from the floodplain.

The High Hazard Containment Alternate for both creeks has a benefit/cost ratio of less than one (1); however, no credit is given in the analysis for life safety. Since life safety is of primary concern to this consultant, this alternate is the basis of our recommendation. The High Hazard Containment Alternate removes all residences from the high hazard flood zone allowing safe evacuation and emergency access during a 100-year flood event. The floodproofing alternate has a high benefit/cost ratio and the dollars spent by individual property owners constructing improvements to protect their individual properties offer significant protection to structures and contents during flood events. A combination of the High Hazard Containment and Floodproofing Alternate is recommended for Reaches 1a, 3, 5, and 6b on Fourmile Canyon Creek and for Reaches 3, and 6 on Wonderland Creek. Additionally, the Floodproofing Alternate is recommended for Reach 6a on Fourmile Canyon Creek and for Reach 2 on Wonderland Creek. .For individual reaches on both creeks these alternates are recommended in tandem.

The benefit/cost ratio of this combined alternate ranges from 0-2.65 on Fourmile Canyon Creek, and 0-5.34 on Wonderland Creek. With implementation of this combined alternate, flood insurance would still be required by most lenders and individual property owners would be strongly encouraged to purchase flood insurance whether or not a mortgage on their property is in effect.

In Reaches 1b, 2a, and 6c on Fourmile Canyon Creek and for Reaches 1, 7, and 8 on Wonderland Creek, no structures are being impacted. For each alternate analyzed, these reaches required no work. Therefore, the Maintain Existing Alternate is recommended for these reaches.

Tables ES.1 and ES.2 summarize the recommended alternate for each reach as well as the B/C ratio and a breakdown of public and private costs for implementing the alternate. In the tables below, it should be noted that the dollar costs listed under the ‘private’ category are for those costs that would be incurred by individual property owners to floodproof their own properties.

**Table ES.1  
Recommended Alternate  
Fourmile Canyon Creek**

| Reach    | Alternate                     | B/C Ratio | Cost         |              |             |
|----------|-------------------------------|-----------|--------------|--------------|-------------|
|          |                               |           | Total        | Public       | Private     |
| Reach 1a | HHZ Containment/Floodproofing | 0.08/0.95 | \$1,583,800  | \$1,025,000  | \$558,800   |
| Reach 1b | Maintain Existing             | 0         | \$1,188,000  | \$1,188,000  |             |
| Reach 2a | Maintain Existing             | 0         | \$442,000    | \$442,000    |             |
| Reach 2b | 100-Year Channel              | 2.65      | \$1,283,660  | \$1,283,660  |             |
| Reach 3  | HHZ Containment/Floodproofing | 0.35/1.18 | \$900,200    | \$741,000    | \$159,200   |
| Reach 4  | 100-Year Channel              | 1.88      | \$6,730,860  | \$6,730,860  |             |
| Reach 5  | HHZ Containment/Floodproofing | 0.12/4.42 | \$798,400    | \$394,000    | \$404,400   |
| Reach 6a | Floodproofing                 | 1.68      | \$3,130,600  | \$290,000    | \$2,840,600 |
| Reach 6b | HHZ Containment/Floodproofing | 0.03/4.44 | \$762,700    | \$595,000    | \$167,700   |
| Reach 6c | Maintain Existing             | 0         | \$173,000    | \$173,000    |             |
| Total    |                               |           | \$16,993,220 | \$12,862,520 | \$4,130,700 |

**Table ES.2**  
**Recommended Alternate**  
**Wonderland Creek**

| Reach   | Alternate                     | B/C Ratio | Cost         |              |             |
|---------|-------------------------------|-----------|--------------|--------------|-------------|
|         |                               |           | Total        | Public       | Private     |
| Reach 1 | Maintain Existing             | 0         | \$618,000    | \$618,000    |             |
| Reach 2 | Floodproofing                 | 0.61      | \$539,400    | \$332,000    | \$207,400   |
| Reach 3 | HHZ Containment/Floodproofing | 0.39/1.37 | \$10,236,600 | \$7,307,000  | \$2,929,600 |
| Reach 4 | 100-Year Channel              | 5.34      | \$7,110,300  | \$7,110,300  |             |
| Reach 5 | 100-Year Channel              | 4.75      | \$4,057,800  | \$4,057,800  |             |
| Reach 6 | HHZ Containment/Floodproofing | 0.51/0.52 | \$5,024,300  | \$3,168,000  | \$1,856,300 |
| Reach 7 | Maintain Existing             | 0         | \$807,000    | \$807,000    |             |
| Reach 8 | Maintain Existing             | 0         | \$289,000    | \$289,000    |             |
| Total   |                               |           | \$28,682,400 | \$23,689,100 | \$4,993,300 |

Figures ES-1a-e and ES-2a-c depict the specific alternate being proposed by this consultant for its Recommended Plan for each reach of each stream.

It is important to realize the Fourmile Canyon Creek and Wonderland Creek floodplains are hydraulically connected. Due to topography and the limited channel capacity of Fourmile Canyon Creek, spills from Fourmile Canyon Creek flow into the Wonderland Creek floodplain. Decisions made on floodplain management and mitigation within the Fourmile Canyon Creek floodplain have a direct impact on the Wonderland Creek floodplain. All development within the existing floodplain should be in accordance with the City, County and Federal permitting requirements.